

**APPLICATION FOR UNITED STATES
LETTERS PATENT**

**SYSTEM AND METHOD FOR SLOT ALLOCATION WITH
REDUCED NEED FOR MEASUREMENT**

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multiplexed radio system with a plurality of base stations having overlapping coverage areas, and particularly to the dynamic apportionment of channels in a multiplexed radio system.

2. Description of the Related Art

In many communication applications, a user with a mobile terminal communicates via a relatively short range radio link with a base station, which may pass his communication to other proximate mobile terminals via the short range link, or which may pass his communication to other base stations or to networks such as the PSTN.

In many such applications a user may roam throughout an area larger than the reliable coverage area of a single base station, yet the user may wish to maintain his communication capability as he roams. Typically, multiple base stations with overlapping coverage areas are provided for such applications.

Since a great many communication services are in place or contemplated, space in the radio spectrum is quite scarce. Thus, while it might be desirable for each base station to have frequencies allocated for its own exclusive use, multiple base stations must operate within lower spectrum bandwidth than ideal, and in many instances must share frequencies. Yet, this must be accomplished while minimizing interference between communication channels, i.e., timeslots in a time-multiplexed system, such as a UMTS/TDD radio system.

Typically, each base station has a number of slots on which it is capable of communicating with mobile stations. In typical conventional systems, when a mobile station wishes to initiate communication the associated base station makes path-loss and interference measurements on each of the slots that it is not presently using, in order to find a slot not being seriously interfered with by another base station or a mobile station.

An existing example of a radio communication system with dynamic channel apportionment is the DECT (Digital European Cordless Telephone) system in which the mobile terminal chooses the slot to be used for communication, without any consideration of the type or quality class (QoS class) of service. There is a need for faster and more reliable operation with more optimal radio resource usage, especially when the requirements of the traffic become more diverse with data and multi-media transmissions.

SUMMARY OF THE INVENTION

An object of the present invention is to reduce the number of slots measured by a base station or a mobile station in order to find a slot not interfered with by another base station or mobile station, and to direct measurements to particular slots determined according to the
5 needed quality class of the communication.

According to one aspect of the invention, a centralized set of information is assembled indicative of the interference patterns among the transmitters (be they base stations or mobile stations) of a particular installation. A slot on which it is found that base stations interfere with each other is assigned as "owned" by one of the base stations and as "avoided" by the other
10 base stations interfered with. A slot on which two adjacent base stations would interfere with each other but is not assigned as owned by either of them is assigned as "shared" by those two base stations. When a slot is to be allocated for communication between a base station and a mobile station, the base station's owned slots that are not presently in use are measured (path-loss measurements are taken) first in an attempt to find one not being interfered with by any
15 other transmitter. If such a slot is found, the communication is assigned to it. If no such owned slot is available, shared slots are measured to find one not interfered with by another transmitter; if one is found, it is used.

In another aspect of the invention, if no owned or shared slot is available, avoided slots will be measured to determine if one is not in use by the owning base station; if one such is
20 found, it is used.

Other objects and features of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference numerals denote similar elements:

Fig. 1 is a block diagram of an environment in which the present invention is deployed;

and

5 Fig. 2 is a flow chart of slot allocation according to the present invention.

1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 depicts a typical environment in which the present invention is useful. A system 10 is deployed in a building which might be an office building, a factory building, a department store, etc. The exemplary embodiment of Fig. 1 depicts a 5-story building, although nothing implicit in the invention constrains it to any particular number of stories or even to deployment in a building; it might, for example, be deployed on terrain, in a plurality of buildings, or in one or more buildings in conjunction with adjacent terrain.

It is desired that users equipped with mobile terminals 4 (of which there typically are many, only one of which is shown in Fig. 1) can always be in communication through the system 10 no matter where they may roam within the system 10. Communication from a mobile terminal 4 is through a base station (BS) 2. Since the system 10 occupies an area larger than the reliable coverage area of a single BS 2, a plurality of BSs 2 are provided. In the exemplary embodiment of Fig. 1, there is a BS 2 near each end of each story of the five-story building, for a total of ten BS 2s denominated 2-1 through 2-10. In accordance with the present invention, a controller 6 is located somewhere in system 10 and has a connection to each of BSs 2. In a present embodiment, the connection is by means of wiring.

A present embodiment of the invention is in a time-division duplex (TDD) system conforming to the Universal Mobile Telecommunication System (UMTS) specification, thus known as a UMTS/TDD system, but the invention is suitable to other systems in which a plurality of transmitters might interfere with one another. All BSs 2 can transmit on the same frequency band, and each BS 2 employs fifteen time-division slots, connoted slots 1 through 15. Taking BS

2-3 as exemplary, an initial assessment might be arbitrarily made that slots of BSs 2-2, 2-4, and 2-8 interfere with BS 2-2. That assessment can be refined over time based on empirical observation. Empirical observation may also indicate that some slots of some BSs other than 2-2, 2-4, and 2-8 interfere with BS 2-3.

5 Based on the current assessment, slots of each BS are assigned as one of owned, shared, or avoided. For example, slots 1, 2, and 3 might be assigned as owned by BS 2-3. Slots 4, 5, and 6 might be assigned as owned by BS 2-2; they would thus be assigned as avoided by BS 2-3. Slots 7, 8, and 9 might be assigned as owned by BS 2-4; they would thus be assigned as avoided by BS 2-3. Slots 10, 11, and 12 might be assigned as owned by BS 2-8; they would thus be assigned as avoided by BS 2-3. Slots 13, 14, and 15 would then be assigned as shared by BS 2-3.

10 When a user requests to initiate communication via mobile terminal 4 (which is in BS 2-3's coverage area), BS 2-3 must allocate a slot for the communication. BS 2-3 determines what slot to use by making path loss measurements between itself and mobile terminal 4 and interference measurements at various slots. The first slots to be tried are those assigned as owned by BS 2-3 (slots 1, 2, and 3 in the present example) and not already in use. If at least one of slots 1, 2, and 3 is not presently in use, the probability is very high that it will be found to be free of interference, since it was assigned as avoided by adjacent base stations. It is thus likely that a usable slot will be found after far fewer measurements than under the prior-art method in which all slots are measured until a usable one is found.

20 However, if slots 1, 2, and 3 are all in use by BS 2-3, or are found to have excessive interference (which might be because of a peculiarity of the present position of mobile terminal 4

or because an adjacent transmitter is using the slot under special permission from controller 6 as will be described below), the slots assigned as shared by BS 2-3 are measured (slots 13, 14, and 15 in the present example). If one of them is found to be sufficiently free of interference, it is used for the communication.

5 In another embodiment of the invention, the quality class required for the communication affects the order of slot measurement. Real-time transmission, for example, requires a high quality class, since lost data are not automatically recovered. Packet data, on the other hand, is transmissible under a lower quality class, since typical protocols automatically retransmit packets which have undergone transmission errors. The term "quality class" is being used herein to
10 connote what is generally known as QoS (quality of service) class. In this embodiment, communications requiring a high quality class start measuring in the slots assigned as owned by a BS, but communications not requiring a high quality class start measuring in the slots assigned as shared by a BS, thus permitting the owned slots (with their higher probability of low interference) to remain available for subsequent high quality class transmissions.

15 In another embodiment of the invention, if neither a BSs owned slots nor its shared slots are available and suitably interference free, controller 6 may grant special permission to a BS to use a slot marked as avoided by that BS and owned by another BS, if controller 6 determines that the other BS is not presently using the slot.

Fig. 2 is a flowchart of initiating a communication according to the present invention. A
20 request indicated to a BS from a user at a mobile terminal 4. (such as by putting the mobile terminal into an off-hook condition) initiates the flow. The flow centers on a particular one of the

BSs, namely the particular BS in whose coverage area a mobile terminal 4 is located when requesting to initiate communication. In the present example, a mobile terminal 4 requesting to initiate communication is in the coverage area of BS 2-3, so BS 2-3 will be treated as central in the present example. The flow of Fig. 2 is entered at block 202. In block 204 it is determined whether a high quality class path is needed. (In some embodiments the check of block 204 may be omitted; control may dispatch directly from block 202 to block 206, and all communications regardless of quality class requirement will be tried on owned slots first.) Blocks 206 and 208 may be repetitively looped through (as indicated by Note 1 on Fig. 2). For each slot owned by BS 2-3 but not currently in use by it, path loss measurements are made in block 206 and the results are evaluated at block 208. As soon as a slot is found with acceptably low interference (indicated by a path loss measurement meeting predetermined criteria) control dispatches block 210 where the communication is established on that slot.

If no owned slots are found with suitably low interference, shared slots are tried next by dispatching to block 212. Blocks 212 and 214 may execute repetitively in the manner of blocks 206 and 208, but for BS 2-3's shared slots. If one is found with suitably low interference, block 210 is reached (through connector "A") and communication is initiated on the found slot.

If control dispatches to block 216, none of BS 2-3's owned slots or shared slots are available for use. Controller 6 (Fig. 1) is interrogated (the interrogation is not shown in Fig. 2) to determine whether any of BS 2-3's avoided slots (which would be slots assigned as owned by other BSs) are in use by their owners, and whether it is permitted for BS-3 to use such slots at this time. If there are any such slots, blocks 216 and 218 may execute repetitively to find one with

suitably low interference. Finding one dispatches to block 210 to initiate communication on that slot. Failure to find one indicates that there are no slots at all available to BS 2-3 at this time. Control dispatches to block 220, and after some predetermined delay time control dispatches back to the beginning of the flow (through connector "B") to try again, on the premise that a communication on some slot may have terminated thus making the slot available, or the interference on some slot may have abated. Not shown in Fig. 2 is that if the user terminates his request to establish communication (as by putting mobile terminal 4 back in an on-hook condition) the flow of Fig. 2 is abandoned.

Thus, while there have been shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.